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(71) Applicant : IWASAKI ELECTRIC CO., LTD.
12-4 Shiba 3-chome Minato-ku
Tokyo 105 (JP)

(72) Inventor : Maseki, Kyoichi
3-19-2, Josai
Gyoda-shi, Saitama-ken (JP)
Inventor : Kurosawa, Kazutoshi
532-2, Kamitanadare, Kisaimachi
Kitasaitamagun, Saitama-ken (JP)
Inventor : Urushihara, Akira
3-17-38, Nishijima
Fukaya-shi, Saitama-ken (JP)

(74) Representative : Jones, Colin et al
W.P. THOMPSON & CO. Coopers Building
Church Street
Liverpool L1 3AB (GB)

(54) Metal halide lamp apparatus.

(57) A metal halide lamp apparatus comprises a reflector (9) and a metal halide lamp which is without an outer bulb and which has a reflecting/thermal insulating film (5) and a frosted portion (6) which is partially formed on the lamp outer surface within a predetermined range continued from the reflecting/thermal insulating film (5). This causes a reduction in an overall illuminance decrease and the attainment of a desired illuminance ratio and prevents the occurrence of irregularity in illuminance and colour. In addition, since electrodes (2a,2b) are asymmetrically disposed, it is possible to decrease the rate of devitrification of the luminous tube and make an attempt to increase the life of the luminous tube.

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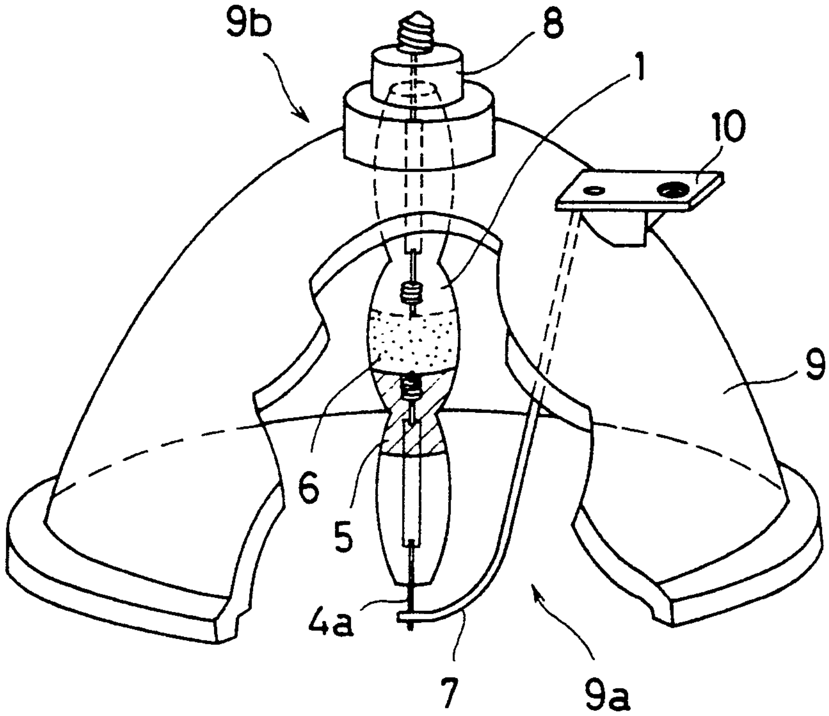
FIG.6



The present invention relates to a metal halide lamp apparatus, and particularly to a metal halide lamp apparatus which comprises a metal halide lamp and a reflecting mirror, which produces a luminous intensity distribution within an optically limited region and which is used as a relatively small image light source.

Conventional small metal halide lamp apparata each comprising a reflecting mirror and a metal halide lamp having a luminous tube and without an outer bulb or envelope, both of which are integrally or detachably combined, are characterized by good colour rendering and high luminous efficiency. Thus, such lamp apparata are used as light sources for overhead projectors, overhead-type liquid crystal projectors, liquid crystal projection televisions, moving picture projectors and so on. Such apparata are becoming increasingly popular.

Halogen lamps are generally used as light sources for the above projectors because it is desirable to use light sources having good colour characteristics. However, although halogen lamps have good colour characteristics, the luminous efficiency thereof is as low as about 30 1m/W. A high-wattage lamp must be thus used for obtaining a large illuminance on a screen. However, the use of a high-wattage lamp has the problems that the size of the apparatus is increased due to the handling of the heat generated from the light source and that a large quantity of heat is generated and cannot be handled easily.

On the other hand, metal halide lamps have a luminous efficiency higher than that of halogen lamps. If at least dysprosium halide is enclosed in a luminous tube, and if a metal halide lamp is operated at an increased vapour pressure of the halide and a decreased arc temperature, the emission of light within the red region is increased, and a spectral distribution having good colour characteristics is obtained.

With reference to Fig. 1 of the accompanying drawings, the conventional metal halide lamps used in the above projections, for example, with a rated lamp power of 150 W, a substantially spherical luminous tube 101 having an electrode spacing of 5mm, the maximum outer diameter Ø11 mm and the maximum inner diameter of Ø8.8 mm is used. Mercury and argon at a pressure of 0.200 bar (150 torr) serving as auxiliary starting gas are enclosed in the luminous tube 101 so that a predetermined lamp voltage is obtained, and dysprosium iodide, neodymium iodide and cesium iodide are enclosed in an amount of 0.5 mg relative to the inner volume of the luminous tube of 0.4 ml at a ratio by weight of 4 : 2 : 3 to form a metal halide lamp.

The luminous tube 101 configured as described above has at respective ends, end wires which are respectively connected to a nickel lead wire 102 and a base 103. A reflector 104 made of hard glass and having a cold mirror film on the surface thereof surrounds the luminous tube 101 coaxially therewith. One end of the lead wire 102 is led to the outside of the reflector 104 and connected to a terminal 105 to form a metal halide lamp apparatus 111.

With reference to Fig. 2 of the accompanying drawings, when the metal halide lamp apparatus 111 configured as described above is used as a light source for a liquid crystal projector, for example, the metal halide lamp apparatus 111 is vertically placed with the bottom or apex up for projecting an image on a screen 115 through a total reflection mirror 112, a liquid crystal panel 113 and a projection lens 114.

In conventional metal halide lamps used in the above-described optical devices, as shown in Fig. 1, a reflecting/heat insulating film 106 is formed in a portion of the outer surface of the lamp in the vicinity of the electrode placed on the open side of the reflector 104, the other portion of the lamp outer surface having a clear surface. When such a metal halide lamp is disposed in the reflector 104 so that the clear surface faces the apex of the reflector 104, as shown in the drawing, and when the lamp is switched on, assuming that the luminous portion of the arc of the luminous tube 101 is placed at the centre of the luminous tube 101, the light emitted from the luminous portion to the clear surface passes substantially straight therethrough, without being scattered by the clear surface.

When the lamp is projected on a screen having an aspect ratio of 3 : 4, as shown in Fig. 3, of the accompanying drawings, through a lens system, the straight or direct light rays emitted from the metal halide lamp through the clear surface is reflected from a portion of the reflector near the lamp and reaches the screen through the lens system. A large quantity of direct light passes through the clear surface, substantially without being scattered, and a large quantity of light directed onto a portion of the mirror 104 near the luminous tube 101 is reflected from the portion because of the low eccentricity of the portion of the reflector 104. When an illuminance distribution along the line A-A′ on the screen was measured, the illuminance in a portion near the centre is extremely high, while the illuminance in the peripheral portion is extremely low, as shown by a curve a in Fig 4 of the accompanying drawings. If an illuminance ratio with respect to the illuminance measured at each of measurement points① to⑨ at the centres of the respective regions which are obtained by dividing the screen in nine equal parts is expressed by the following equation:

$$\text{Illuminance ratio (\%)} = \frac{\text{Minimum illuminance value at measurement points ① to ⑨}}{\text{Illuminance value at centre (illuminance value at measurement point ⑤)}} \times 100$$

when a metal halide lamp comprising a luminous tube most of which has a clear surface is used, the illuminance ratio is as low as about 10%.

It is considered on the basis of experience that the illuminance ratio is preferably 30% or more from the visual viewpoint. The use of a metal halide lamp most of which has a clear surface, as described above, has the problem that irregularity is produced in the illuminance on the screen due to a low illuminance ratio, resulting in a displeasing appearance of the projected image.

On the other hand, as shown in Fig.5 of the accompanying drawings, it is thought that a frosted portion 121 should be formed over the whole surface of the luminous tube 101 in order to remove the displeasing appearance caused by the irregularity in illuminance. The frosted portion 121 is formed on the outer surface of the luminous tube by a satinising treatment, i.e., sand blast processing, in which glass beads are sprayed on the clear outer surface of the luminous tube by using high-pressure gas. In the luminous tube having the thus-obtained frosted portion 121, as shown in Fig.5, about half of the light 122 emitted from the luminous portion at the centre of the luminous tube travels as direct light rays 123 from the frosted portion 121, the remainder light travelling from the frosted portion 121 as light rays 124 scattered in the vicinity of the straight light 123.

When the luminous tube 101 in which the frosted portion 121 is formed on the whole surface thereof except that the thermal insulating film 106 is disposed in the reflector for projecting light on a screen, the direct light rays 123 in an amount of about half of the emitted light is applied to a portion of the reflector, which has relatively large eccentricity, is reflected therefrom and reaches the vicinity of the centre of the screen. Only a small quantity of scattered light 124 reaches the vicinity of the centre and the peripheral portion of the screen. When the illuminance distribution along the line A-A′ on the screen is measured, a curve b shown by a dotted line in Fig.4 is obtained. As seen from the measurement of illuminance, although the provision of the frosted portion permits an increase in the illuminance ratio, there is the problem that a desired illuminance cannot be obtained at the centre of the screen because of a decrease in the overall illuminance, and that a large quantity of light is uselessly scattered.

Conventional metal halide lamp apparata also have the following problems: When the vapour pressure of the enclosed metal halide is increased by increasing the temperature of the luminous tube wall in a metal halide lamp, good colour characteristics are obtained. However, when the metal halide lamp is vertically disposed and used, if a bare luminous tube without an outer bulb is used, the temperature difference between the upper and lower portions of the inner surface of the quartz container which forms the luminous tube is increased, as compared with the case of a luminous tube with an outer bulb. If a desired vapour pressure is obtained by increasing the temperature of the lower portion (coolest portion) of the luminous tube containing a melted enclosed filling to substantially the same temperature as that of a lamp with an outer bulb, therefore, the temperature of the upper portion of the inner surface of the quartz container is increased excessively. Particularly, in the case of a lamp in which dysprosium is enclosed for improving the colour characteristics, devitrification occurs in the upper portion of the luminous tube in an early stage.

In this case, although the overall luminous flux is only slightly changed, the colour temperature of the colour characteristics is decreased due to the heat insulating effect caused by the devitrification, and the illuminance on the screen is further decreased due to an increase in scattering caused by the devitrification. There are thus the problems that the screen is darkened or discoloured, and that the lamp voltage is further increased.

Accordingly, it is an object of the present invention to provide a novel metal halide lamp apparatus which has none of the above problems of conventional metal halide lamp apparatuses.

It is another object of the present invention to provide a metal halide lamp apparatus which provides optimum illuminance on a screen without producing irregularity in illuminance and colour on the screen.

It is a further object of the present invention to provide a metal halide lamp apparatus with a long life which not only provides optimum illuminance on a screen without producing irregularity in illuminance and colour on the screen but also prevents devitrification from being produced by dysprosium in the inner surface of a quartz container which forms a luminous tube.

In order to solve the above problems, in an aspect of the present invention, a metal halide lamp apparatus comprises a reflector having a parabolic or ellipsoidal reflecting surface, and a metal halide lamp without an outer bulb disposed in front of the reflector so that the axis connecting both electrodes substantially agrees with the axis of the reflector, wherein the metal halide lamp has a reflecting/thermal insulating film which is formed on a portion of the lamp outer surface in the vicinity of the electrode placed on the open side of the reflector, and a frosted portion which is formed in a portion of the lamp outer surface which has one end at the edge of the reflecting/thermal insulating film and the other end ranging from a position near the centre between both electrodes to a position near the centre of a coil or equivalent enlargement of the electrode placed on the apex side of the reflector.

In the invention, the frosted portion is not formed over the whole outer surface of the lamp, but it is partially formed in a portion of the lamp outer surface which has one end at the edge of the reflecting/thermal insulating film and the other end ranging from a position near the centre between both electrodes to a position near the centre of the coil of the electrode placed on the apex side of the reflector so as to reduce a decrease in the overall illuminance, and a desired level of illuminance at the centre of a screen is obtained when light is projected on to the screen. It is thus possible to decrease irregularity in illuminance by increasing the illuminance ratio to 30% or more and obtain a clear image by improving the average illuminance of the screen.

In another aspect of the present invention, a metal halide lamp apparatus comprises a reflector having a parabolic or ellipsoidal reflecting surface, and a metal halide lamp without an outer bulb disposed in front of the reflector so that the axis connecting both electrodes substantially coincides with the axis of the reflector, the axis of the metal halide lamp being vertically disposed during use, wherein the metal halide lamp has a reflecting/thermal insulating film which is formed on a portion of the lamp outer surface in the vicinity of the electrode placed on the open side of the reflector, and a frosted portion which is formed in a portion of the lamp outer surface which has one end at the edge of the reflecting/thermal insulating film and the other end ranging from a position near the centre between both electrodes to a position near the centre of a coil or equivalent enlargement of the electrode placed on the apex of the reflector, and the electrode which is an upper electrode during lighting has a portion projecting from the inner wall of the luminous tube, a ratio of the length L_u of the projecting portion to the length L_d of the projecting portion of the lower electrode being set to a value within the range of $1.2 \leqq L_u/L_d \leqq 1.8$.

In this way, the partially formed frosted portion has the function of decreasing the irregularity in illuminance and thus increasing the average illuminance. In addition, the electrode portions are asymmetrically disposed so that the difference between the temperature distributions in the upper and lower portions of the luminous tube is decreased even when a bare luminous tube without an outer bulb is used. Even when a dysprosium halide is enclosed in a luminous tube for obtaining a light source having good colour characteristics, therefore, the rate of devitrification caused by an increase in the temperature of the quartz luminous tube is decreased, and the upper end of the luminous tube having a large optical utilisation factor can be sufficiently utilised during the life of the lamp. This permits a reduction in the illumination decrease, an increase in the factor of maintenance of the screen illuminance at a high level and increases in the life and the luminous efficiency of the lamp.

The invention is further described, by way of example, with reference to the accompanying drawings, in which:-

Fig. 1 is a partially broken-out side view of a conventional metal halide lamp apparatus;

Fig. 2 is a schematic drawing of a liquid crystal projector which uses a metal halide lamp apparatus;

Fig. 3 is a drawing showing a screen used for measuring average illuminance and an illuminance ratio;

Fig. 4 is a graph showing the illuminance distribution along the line A-A′ on the screen shown in Fig. 3 when light is projected on the screen from a conventional metal halide lamp apparatus;

Fig. 5 is an illustration of a conventional lamp having a frosted portion formed over the whole outer surface of a luminous tube;

Fig. 6 is a partially broken-out side view of a metal halide lamp apparatus in accordance with one embodiment of the present invention;

Fig. 7 is an enlarged side view of the luminous tube shown in Fig. 6;

Fig. 8 is a graph showing the illuminance distribution produced when light is projected on a screen from the metal halide lamp apparatus shown in Fig. 6;

Fig 9 is a sectional elevation showing the paths of light emitted from the luminous tube shown in Fig. 6;

Fig. 10 is a graph showing a relation between the ratio of the frosted portion formed in the lamp outer surface and the average illuminance of a screen;

Fig. 11 is an enlarged side view, showing a luminous tube in accordance with a second embodiment of the present invention; and

Fig. 12 is a schematic drawing showing an example of the arrangement of an overhead projection TV which uses the metal halide lamp apparatus shown in Fig. 11.

The prior art lamp apparata of Figs. 1 to 5 have already been described.

A metal halide lamp apparatus according to a first embodiment of the present invention is shown in Figs. 6 and 7 to which reference will now be made.

Fig. 6, the reflector of the metal halide lamp apparatus is partially broken away. A luminous tube 1 comprises a quartz container having a maximum outer diameter of 11 mm, a maximum inner diameter of 8.8 mm, content volume of 0.4 ml and an elliptical cross-sectional form. As shown in Fig. 7, electrodes 2a, 2b are provided in the luminous tube 1 at respective ends thereof and are at a distance of 5 mm apart. Each of the electrodes 2a, 2b has a closely wound coil which is formed by winding a tungsten wire having a diameter of 0.32 mm in a coil length of 2.5 mm on a tungsten core having a diameter of 0.45 mm and a length of 6.5 mm and containing $Th0_2$, the coil being disposed at a distance of 0.5 mm from the tip of the core.

Edged molybdenum foils 3a, 3b each of which has a width of 1.5 mm and a length of 12 mm and which are welded to the electrodes 2a, 2b respectively, are provided in sealed portions for maintaining the airtightness in the luminous tube 1. Molybdenum wires 4a, 4b each having a diameter of 0.6 mm are connected to the other ends of the foils 3a, 3b, respectively, so that electric power is supplied from the outside through the wires 4a, 4b. In the luminous tube 1 are enclosed mercury, argon and 0.5 mg of three iodides, ie., dysprosium iodide, neodymium iodide and cesium iodide, at a ratio by weight of 4 : 2 : 3.

In addition, a reflecting/thermal insulating film 5 which has light reflection and heat resistance and which is made of a $A1_20_3$-$Si0_2$ mixture or the like, is formed by coating onto a portion of the outer surface of the lamp in the vicinity of the electrode 2a placed on the open side 9a of the reflecting mirror 9 described below. Further, a frosted portion 6 is formed by frosting a portion of the lamp outer surface within the range from the edge 5a of the thermal insulating film 5 to a position near the end of the electrode 2b placed on the apex side 9b of the reflecting mirror 9 beyond a position corresponding to the centre between the two electrodes 2a, 2b.

The wires 4a, 4b of the luminous tube 1 configured as described above are respectively connected to a nickel lead wire 7 and a base 8, as shown in Fig. 6, and the reflector 9 made of hard glass and having a cold mirror film on the inner surface thereof and ∅ 90 mm and f of 15 is provided so as to surround the luminous tube 1. In this case, the axis of the reflector 9 substantially coincides with the axis of the luminous tube 1. One end of the lead wire 7 is led to the outside of the reflector 9 and is connected to a terminal 10 to form a metal halide lamp apparatus.

When the metal halide lamp apparatus is switched on at a rated power of 150W by an electronic ballast using a rectangular wave of about 270 Hz, the lamp apparatus shows such luminous characteristics that the overall luminous flux is 12000 1m, the colour rendering index of Ra85, the colour temperature is 7000K and luminous efficiency is 80 1m/W, and has excellent characteristics as an image light source.

When light was projected on the screen shown in Fig. 3 by a predetermined optical system, average illuminance of 4000lx was obtained. In addition, when the illuminance distribution was measured along the line A-A' on the same screen, the illuminance characteristics shown by the curve c shown by a chain-dotted line in Fig. 8 were obtained, and the illuminance ratio was 30%, without producing irregularity in illuminance and colour. The curves a, b shown in Fig. 4 are also shown in Fig. 8 for comparison.

Reasons why the high average illuminance and appropriate illuminance ratio are obtained are the following: As shown in Fig. 9, the light 11 passing through the clear portion 1a on the apex side 9b of the reflector 9 travels straight from the lamp surface without being scattered, is reflected from the reflector 9 and then projected onto the central portion of the screen. Since the light passing through the clear portion 1a travels straight, without being scattered, as described above, the illuminance in the central portion on the screen is high.

On the other hand, about half of the light emitted towards the frosted portion 6 passes through the frosted portion 6 as it was ie. is unscattered, and travels straight and, to some extent, it is applied to a portion away from the central portion on the screen. Rays of light D_1, D_2 scattered by the frosted portion 6 are applied to the central or peripheral portion of the screen. This state where the light emitted from the luminous portion of the luminous tube 1 travels from the lamp surface in the above-described manner produces the illuminance distribution characteristics shown by the curve c shown by the chain-dotted line in Fig. 8.

In the present invention, the reflecting/thermal insulating film 5 is provided on a portion of the lamp surface in the vicinity of the electrode placed on the open side of the reflector of the lamp. The present invention thus has the functional effect described below. If such a reflecting/thermal insulating film 5 were not provided, much of the light emitted from the central luminous portion of the luminous tube 1 towards a region corresponding to a portion having the reflecting/thermal insulating film formed thereof would travel in the direction in which it is not applied to the reflector. In an apparatus such as an overhead projector or the like, which uses such a metal halide lamp apparatus, therefore, stray light which does not reach the screen would be produced. When the reflecting/thermal insulating film 5 is provided, as in the invention, the light emitted from the central luminous portion of the luminous tube 1 is irregularly reflected from the reflecting/thermal insulating film 5 and again returned to the central luminous portion so as to be effectively utilised, thereby increasing the luminous efficiency. In addition, since the vapour pressure of the substance enclosed in the lamp is increased due to the reflecting/thermal insulating film 5, the quantity of light is increased, and thus the luminous efficiency is further increased.

As described above, in the present invention, the frosted portion 6 is partially formed over a predetermined range of the outer surface of the lamp. A description will now be given of the experiment performed for determining the optimum region for the formation of the frost portion.

In Fig.7, the length from the edge 5a of the reflecting/thermal insulating film 5 to the inner wall end 1b of the luminous tube 1 adjacent the electrode 2b is denoted by L, and the length from the edge 5a of the reflecting/thermal insulating film 5 to the end 6a of the frosted portion 6 is denoted by 1. Various lamps having different I/L values, ie., frosted portions 6 having difference lengths, were prepared. The reflector 9 was then provided as shown in Fig. 6, and the average illuminance relative to each of the I/L values was measured with constant lamp input of 150 W under the condition that the average illuminance of the measurements at the nine points on the screen was adjusted to the maximum. The results shown by the solid line in Fig.10 were obtained. In Fig.10, the abscissa shows the I/L values (%), 0% shows a case wherein no frosted portion was formed in the lamp outer surface, and 100% shows a case wherein the frosted portion was formed over the whole outer surface of the lamp. The ordinate shows the average illuminance (lx) on the screen.

The average illuminance of the nine points on the screen is an average of the measured values obtained by measuring the illuminance in the central portions① to⑨ of the nine equal sections of the screen shown in Fig.3. In Fig.10, each of the values on the solid line represents the ratio or illuminance ratio of the minimum illuminance to the maximum illuminance on the screen, which illuminance ratio indicates the degree of irregularity in illuminance.

As seen from Fig.10, comparison between the screen illuminance ratio shown at each of the plotted points on the solid line and the average illuminance reveals that, when the I/L value is about 10%, although the average illuminance is as high as about 5000 lx, the illuminance ratio is about 20%, and the irregularity in illuminance is large. It is also found that, when the I/L value is about 80%, although the illuminance ratio is increased to about 34%, the average illuminance is decreased to about 3500 lx.

A relation between the I/L value and the average illuminance was then determined under the conditions that the illuminance ratio was kept at 30% because an illuminance ratio of 30% or more is visually required, and that the relative position between the lamp and reflector was adjusted so that the average illuminance was the maximum. As a result, the results shown by the broken line in Fig.10 were obtained.

As seen from the measurement curves shown by the solid and broken lines in Fig.10, if the I/L value which shows the ratio of the frosted portion formed in the lamp outer surface is within the range from 25 to 70%, a good illuminance ratio of 30% or more and a good average illuminance of 4000 lx or more are obtained. Namely, the I/L range permits a decrease in irregularity in illuminance on the screen, the formation of a bright image on the screen and the attainment of good optical characteristics.

When the I/L value is less than 25%, for example, 20%, if the illuminance ratio is 30%, since the average illuminance is 3900 lx or less, the screen is darkened, and a good image cannot be thus obtained. If an attempt is made to brighten the screen by increasing the average illuminance to 4000 lx or more, eg., 4500 lx, since the illuminance ratio is decreased to about 24%, the irregularity in illuminance is remarkable. On the other hand, if the I/L value exceeds 70%, the illuminance ratio is increased, and the irregularity in illuminance is decreased. If, for example, the I/L value is 80%, since the average illuminance is 3500 lx or less, the screen is darkened, and thus a good image cannot be obtained. If the I/L value is less than 25% or over 70%, therefore, good optical characteristics are not obtained.

On the basis of the above measured values, a positional relation of the luminous portion of the luminous tube, the electrodes or the like to the optimum I/L range from 25 to 70% for the frosted portion formed in the lamp outer surface in the invention was examined. The results obtained were the following:

It was shown by the examination that a I/L value of 25% corresponds to a case wherein the frosted portion 6 is formed in a portion of the lamp outer surface within the range from the edge 5a of the reflecting/thermal insulating film 5 to substantially the centre 1c (refer to Fig. 7) between the two electrodes. It was also shown that a I/L value of 70% corresponds to a case wherein the frosted portion 6 is formed in a portion of the lamp outer surface within the range from the edge 5a of the reflecting/thermal insulating film 5 to substantially the centre of the coil of the electrode 2b placed on the apex side of the reflector.

In the present invention, the range of the frosted portion formed is therefore determined to a portion of the lamp outer surface which has one end at the edge of the reflecting/thermal insulating film and the other end ranging from a position near the centre between the two electrodes to a position near the centre of the coil of the electrode placed on the apex side of the reflector.

In the above first embodiment, the frosted portion is partially formed so that the irregularity in illuminance is decreased, and the average illuminance on the screen is improved, as described above. In the metal halide lamp configured as described above, if an attempt is made to increase the temperature of the open side 9a (coolest portion) of the reflector 9 of the luminous tube 1 so that the colour characteristics are improved by further increasing the vapour pressure of the enclosed metal halide, the temperature of a portion in the inner surface of the luminous tube 1 on the apex side 9b of the reflector is significantly increased. In a lamp in which dysprosium is enclosed, because devitrification occurs in the quartz container which forms the luminous tube in an early stage, the illuminance on the screen is significantly decreased, and the colour characteristics sometimes deteriorate.

A second embodiment is designed so that the life thereof is increased by suppressing the devitrification. Fig. 11 is a side view of the lamp portion of the second embodiment. In the drawing, a luminous tube 21 comprises a light-transmitting quartz container having a substantially elliptical cross-sectional form and a luminous portion at the centre thereof. An upper electrode 22b is provided in an upper portion of the luminous tube 21, the upper electrode 22b having a closely wound coil which is formed by winding a tungsten wire having a diameter of 0.35 mm in a coil length of 2.5 mm on a tungsten core having a diameter of 0.5 mm and a length of 8.5 mm and which is disposed at a distance of 0.5 mm from the tip of the core. A lower electrode 22a which is the same as the upper electrode except that the length of the core is 6.5 mm is provided in a lower portion of the luminous tube 21.

In the present invention, the upper electrode 22b projects by a length of L_u to the projecting length L_d of the lower electrode 22a being set a value within the range of $1.2 \leqq L_u/L_d \leqq 1.8$ which is suitable for suppressing the devitrification. In this embodiment, L_u is 6mm, L_d is 4 mm, and the ratio of L_u/L_d is set to 1.5.

The electrodes 22a, 22b are connected to molybdenum foils 23a, 23b, respectively, for maintaining the electrical connection and airtightness of the quartz container. Molybdenum lead wires 24a, 24b are connected to the molybdenum foils 23a, 23b, respectively, so that electric power is supplied from both ends of the wires.

The luminous tube has a content volume of about 0.6 cc, a maximum outer diameter of 11 mm, a maximum inner diameter of 8.8 mm and an arc length of 5 mm, the total length of the luminous portion being longer than that of the luminous tube in the first embodiment. Dysprosium iodide, neodymium iodide and cesium iodide in an amount of 0.6 mg at a ratio by weight of 4 : 2 : 3 and mercury and argon are enclosed as luminous substances in the luminous tube 21. A reflecting/thermal insulating film 25 mainly composed of zirconium oxide is coated on a portion of the outer surface of the luminous tube in the vicinity of the lower electrode 22a.

A frosted portion 26 is formed in the outer surface of the luminous tube 21 over the range from the edge 25a of the reflecting/thermal insulating film 25 to a position near the end of the upper electrode 22b in the same way as in the first embodiment.

A parabolic reflector made of hard glass and having a cold mirror formed on the inner surface thereof and an outer diameter of 100 mm is provided on the luminous tube 21 configured as described above in the same way as in the first embodiment. The reflector is vertically disposed so that light is emitted from the open side of the reflector. For example, a colour filter and an image liquid crystal are optically disposed in front of the lamp so that light is projected by using a lens to form an overhead projection TV. Fig. 12 is a schematic drawing of the overhead projection TV which comprises a metal halide lamp apparatus 31 according to this embodiment; total reflection mirrors 32, 33, 34; colour filters 35, 36, 37, 38 (dichroic mirrors); transmission type image liquid crystals 39, 40, 41; a projection lens 42; and a screen 43.

When the metal halide lamp apparatus having the above arrangement is vertically disposed and switched on by an electronic blast with a rectangular wave of 270 Hz and rated lamp power of 150 W so that light is projected on the screen, the apparatus exhibits such excellent characteristics that the total luminous flux is 12500 1m, the colour temperature is 7000K, the colour rendering index Ra is 85, the special colour rendering index Rg is 60, the average illuminance is 4100 lx and the illuminance ratio is 35%.

A description will now be given of the experiment performed for determining the above-described range of ratios of the projection length L_u of the upper electrode 22b to the projection length L_d of the lower electrode 22a in the luminous tube in the present invention.

A metal halide lamp apparatus was formed with the same arrangement as that of the second embodiment shown in Fig. 11 except that the projection length L_u=4 mm of the upper electrode 22b was equal to the projection length L_d of the lower electrode 22a, and the arc length was 7 mm. The metal halide lamp apparatus was used as a light source for an overhead projection TV. When the screen illuminance obtained after the lamp apparatus had been used for 500 hours was compared with the initial value, it was found that the average illuminance is reduced by half, and the central illuminance is reduced to half or less.

When the luminous tube was immediately discharged and examined, a cloudy portion caused by devitrification was observed in the luminous tube near the upper electrode 22b. It was found that, since the light emitted from the central luminous portion to the devitrified portion does not reach the reflector effectively because the light is scattered by the devitrified portion, the screen illuminance is decreased, and the central illuminance is most decreased. It was also found that the remarkable devitrification in a portion of the inner surface of the quartz container which forms the luminous tube near the upper electrode 22b is caused by a significant increase in the temperature of the portion of the inner surface of the quartz container near the upper electrode 22b.

Experiment was thus made under the condition that the length L_u of the portion of the upper electrode 22b projecting from the inner wall of the luminous tube was longer than the length L_d of the projecting portion of the lower electrode 22a in order to retard the occurrence of devitrification in an upper portion of the luminous tube which is effective to light emission. As a result, it was found that the rate of devitrification depends upon the lengths of the projecting portions. Namely, a luminous tube was formed with an arrangement in which the length of the core of the upper electrode 22b was 8.5 mm which was about 2 mm longer than that of the core of the lower electrode 22a in the same way as in the second embodiment, the projecting length of the upper electrode 22b was 6 mm, and the arc length was 5 mm, with the quartz container having the same shape and dimensions. When the surface temperature of the luminous tube was examined with a rated electric power of 150 W, it was found that, although the temperature of the central portion of the luminous tube was increased, the temperature of the portion near the upper electrode 22b was only slightly increased, substantially like the portion near the lower electrode, as compared with the lamp in which the projecting length of the upper electrode is equal to that of the lower electrode.

When the luminous tube configured as described above was attached to a reflecting mirror for measuring illuminance, the central illuminance was increased by 20% as compared with the lamp in which the projecting lengths of both electrodes are equal to each other, and the peripheral illuminance was substantially the same as with that lamp. In addition, when illuminance was measured after the luminous tube formed had been used for 500 hours in a state wherein it was mounted in an optical device, the attenuation rate was 25% which was significantly improved as compared with the lamp in which the projecting lengths of the upper and lower electrodes were the same.

Further, various luminous tubes having upper electrodes having different projecting lengths L_u were formed and used for experiment. As a result, it was found that, if the projecting length L_u of the upper electrode 22b is less than a value of 1.2 times the projecting length L_d of the lower electrode 22a, there is substantially no effect. It was also found that, if the projecting length L_u exceeds a value of 1.8 times the projecting length L_d, a desired vapour pressure cannot be obtained, the colour and luminous distribution deteriorate, and the usable lamp state cannot be obtained.

In the present invention, the ratio of the projecting length L_u of the upper electrode to the projecting length L_d of the lower electrode is therefore set to a value within the range of $1.2 \leqq L_u/L_d \leqq 1.8$. When the ratio is set within this range, the luminous tube maintains illuminance sufficiently and can be used as a light source having characteristics which have no problem for practical use even if the luminous tube has a longer shape and an arc length of, for example, 7.5 mm.

In the second embodiment shown in Fig.11, the illuminance ratio to the ratio l/L of the frosted portion in the outer surface of the lamp and screen average illuminance were measured by the same method as that in the first embodiment. As a result, a plot curve showing the same tendency as that shown in Fig.10 was obtained.

Namely, when the ratio l/L is defined to the range from 25% to 70%, a bright screen having a high screen average illuminance, a high illuminance ratio and low irregularity in illuminance is obtained, and good optical characteristics are thus obtained.

Claims

1. A metal halide lamp apparatus comprising a reflector (9) having a parabolic or ellipsoidal reflecting surface or the like; and a metal halide lamp without an outer bulb disposed in front of said reflector (9) so that the axis along which two electrodes (2a,2b) of the lamp lie substantially coincides with the axis of said reflector (9), wherein said metal halide lamp has a reflecting/thermal insulating film (5) formed on a portion of the lamp outer surface in the vicinity of the electrode (2a) placed on the open side of said reflector (9), characterised in that a frosted portion (6) is formed in a portion of the lamp outer surface and has one end at the edge of said reflecting/thermal insulating film (5) and the other end ranging from a position near the centre between the two electrodes (2a,2b) to a position near the centre of a coil or its equivalent of the electrode placed on the apex side of said reflector (9).

2. A metal halide lamp apparatus comprising a reflector (9) having a parabolic or ellipsoidal reflecting surface or the like; and a metal halide lamp without an outer bulb disposed in front of said reflector (9) so that the axis along which two electrodes (2a,2b) of the lamp lie substantially coincides with the axis of said reflector (9), the axis of said metal halide lamp being vertically disposed during use, wherein said metal halide lamp has a reflecting/thermal insulating film (5) formed on a portion of the lamp outer surface in the vicinity of the electrode placed on the open side of said reflector (9), characterised in that a frosted portion (6) is

formed in a portion of the lamp outer surface which has one end at the edge of said reflecting/thermal insulating film (5) and the other end ranging from a position near the centre between the two electrodes (2a,2b) to a position near the centre of a coil or its equivalent of the electrode (2b) placed on the apex side of said reflector (9) and, if the length of a portion of an electrode (2b) projecting from the inner wall of said luminous tube, which electrode is an upper electrode during lighting, is L_u, and the length of a projecting portion of an electrode (2a) which is a lower electrode during lighting is L_d, a ratio of L_u to L_d is set to a value within the range of $1.2 \leqq L_u/L_d \leqq 1.8$.

3. A metal halide lamp apparatus according to claim 1 or 2, wherein, assuming that the length from the edge of said reflecting/thermal insulating film (5) formed on the outer surface of said metal halide lamp to the inner wall end of said luminous tube on the apex side of said reflector (9) is L, and the length from the edge of said reflecting/thermal insulating film (5) to the end of said frosted portion is l, a ratio of l/L is set to a value within the range of 0.25 to 0.7

4. A metal halide lamp apparatus according to claim 1, 2 or 3, wherein at least dysprosium halide is enclosed in said metal halide lamp.

FIG.1

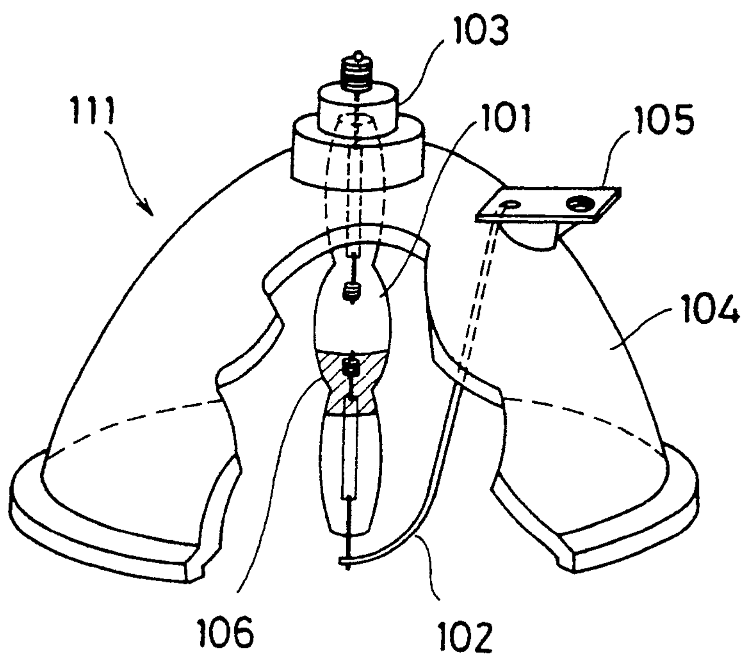


FIG.2

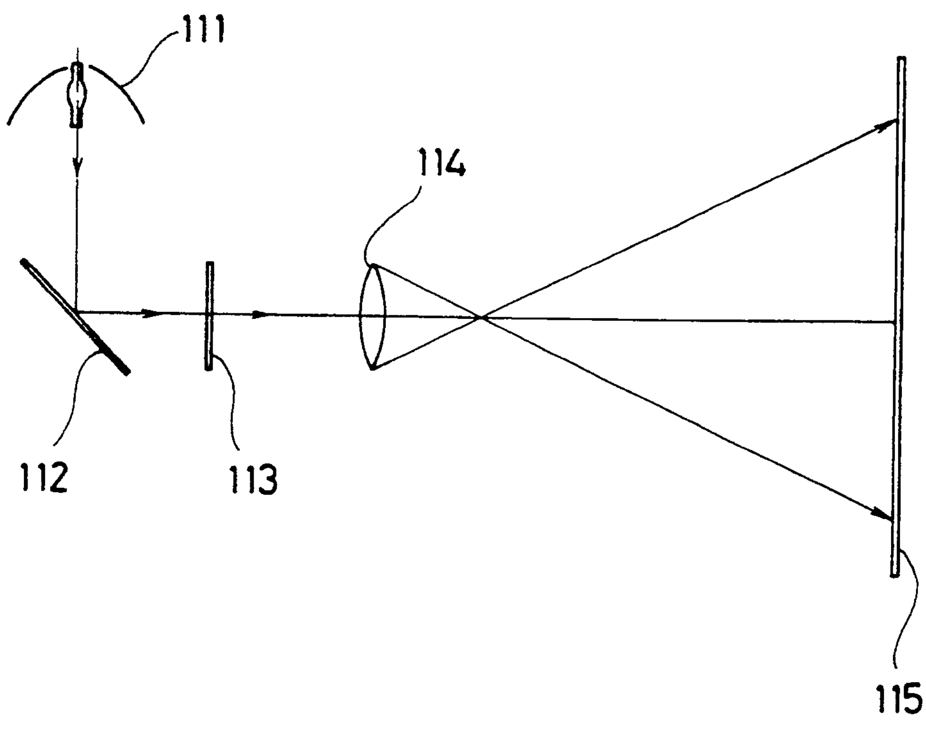


FIG.3

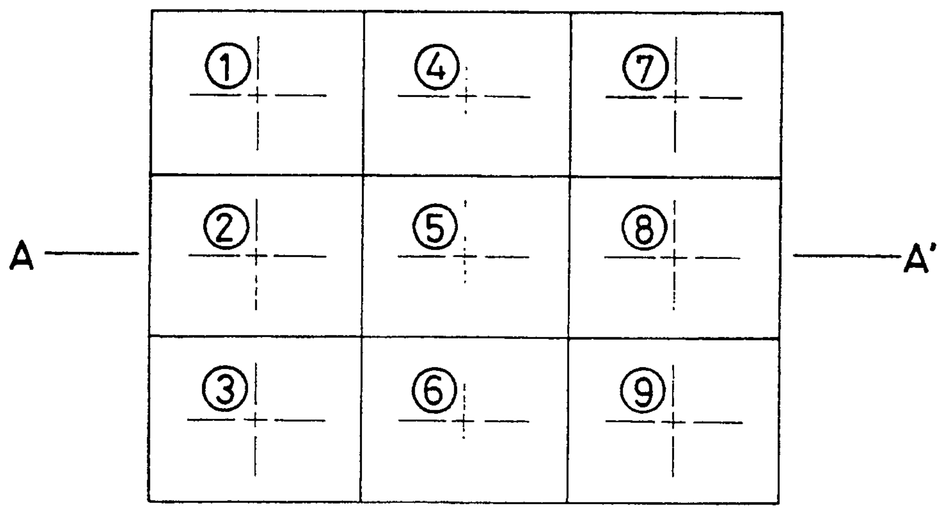


FIG.4

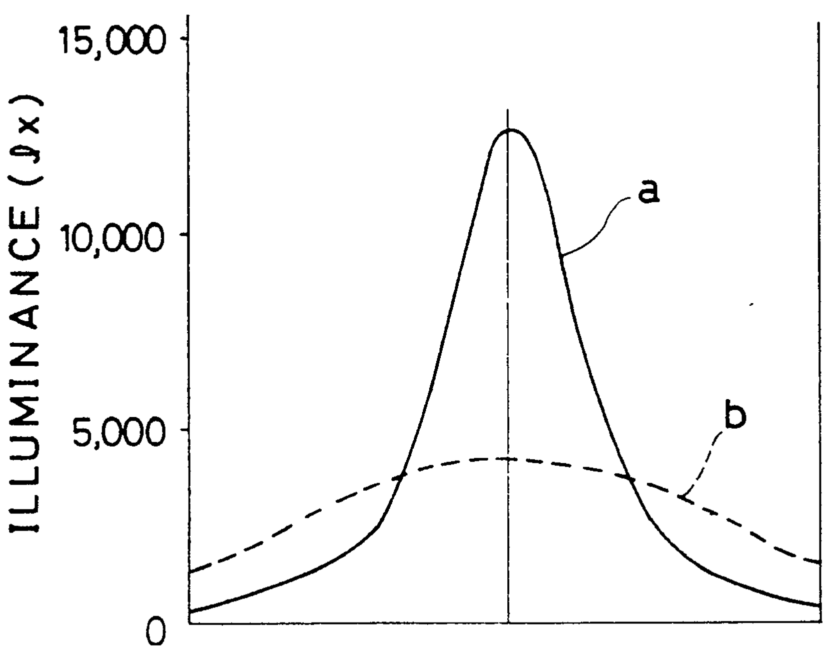


FIG.5

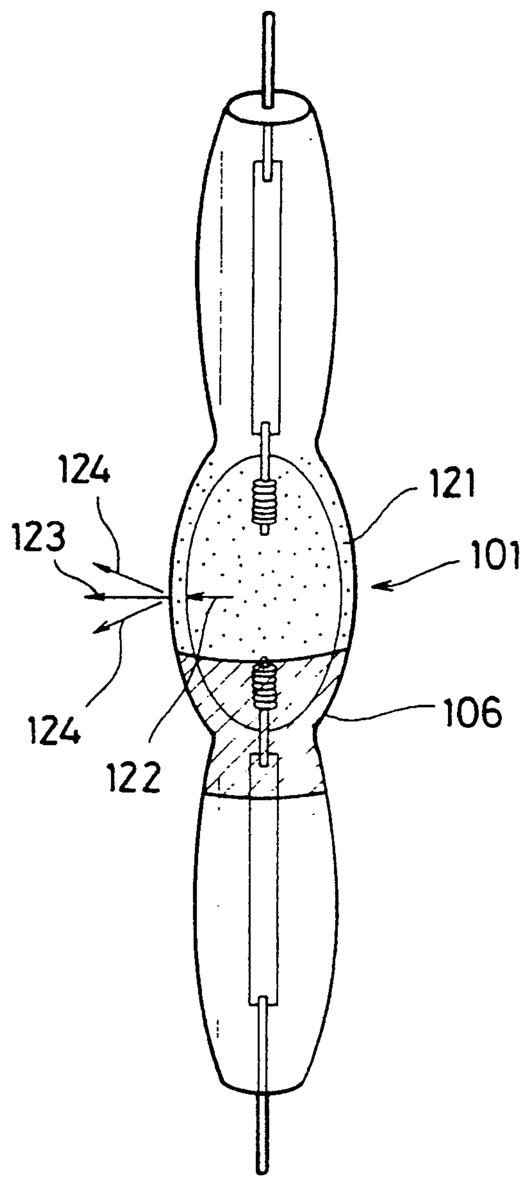


FIG.6

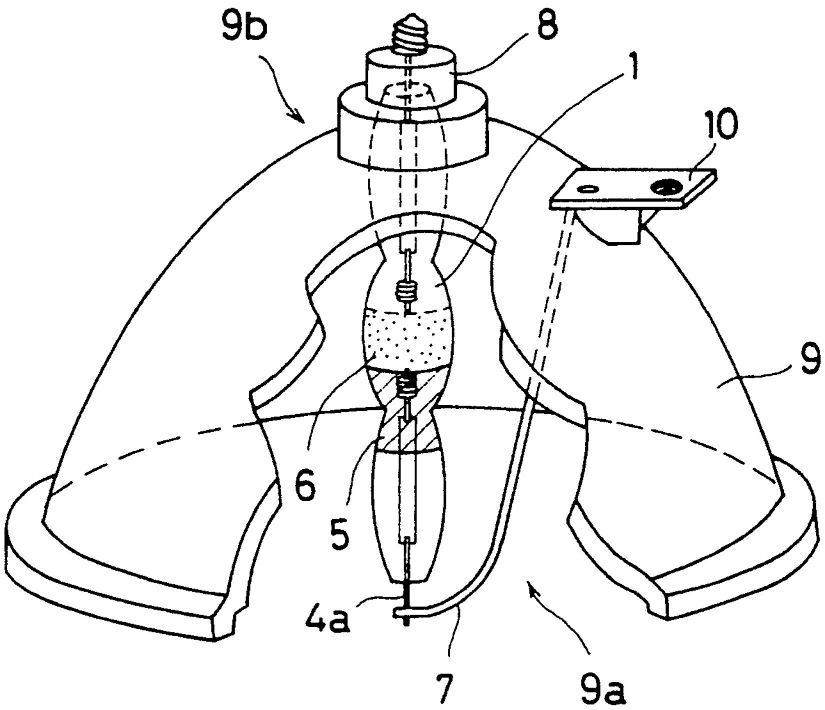


FIG.7

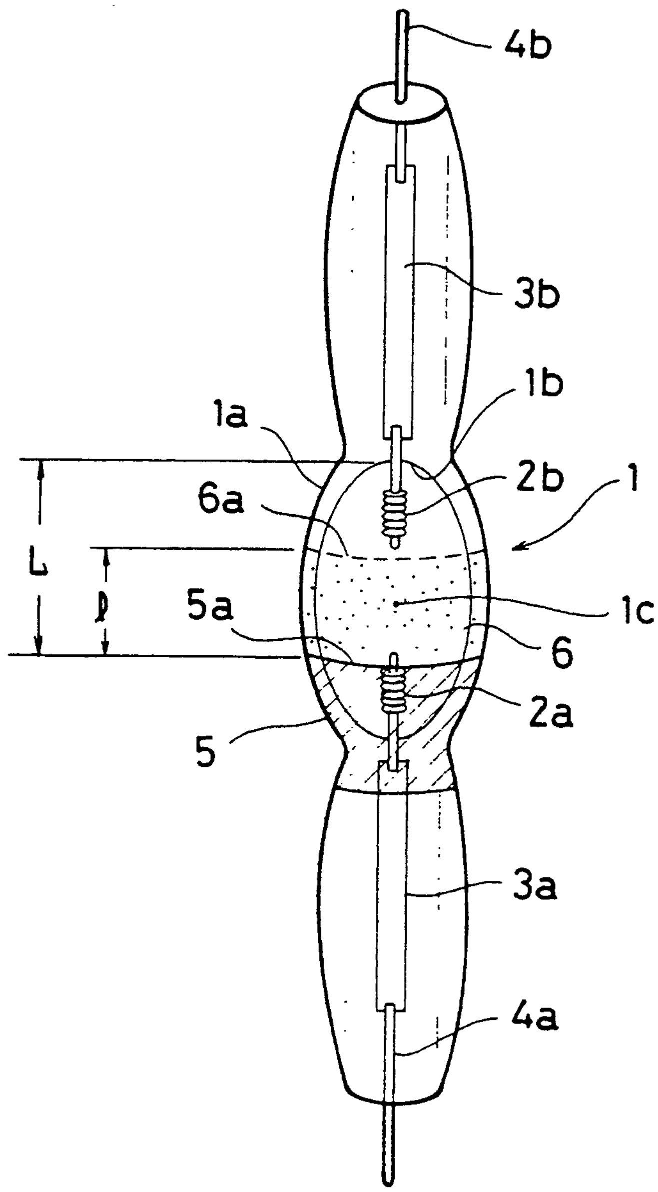


FIG.8

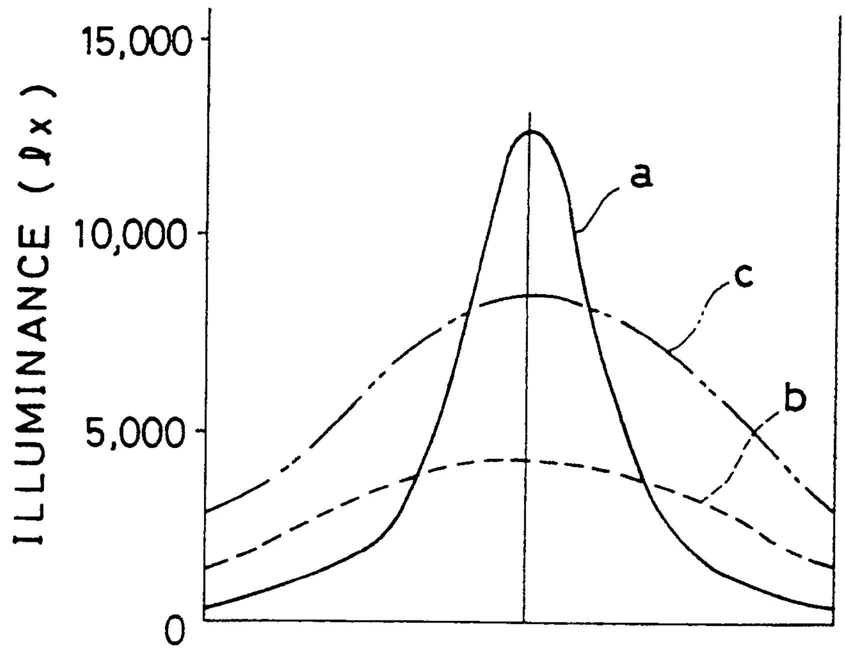


FIG.9

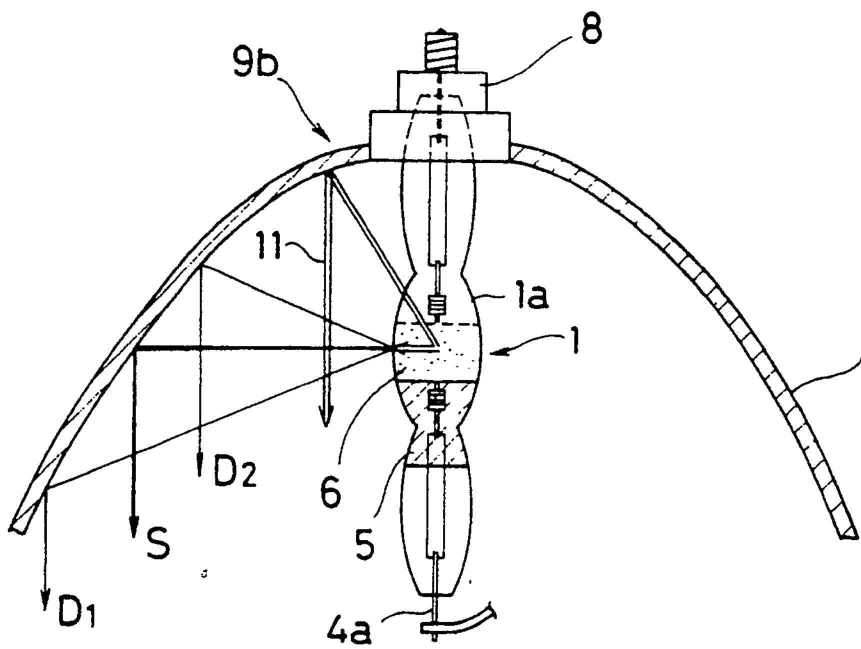


FIG.10

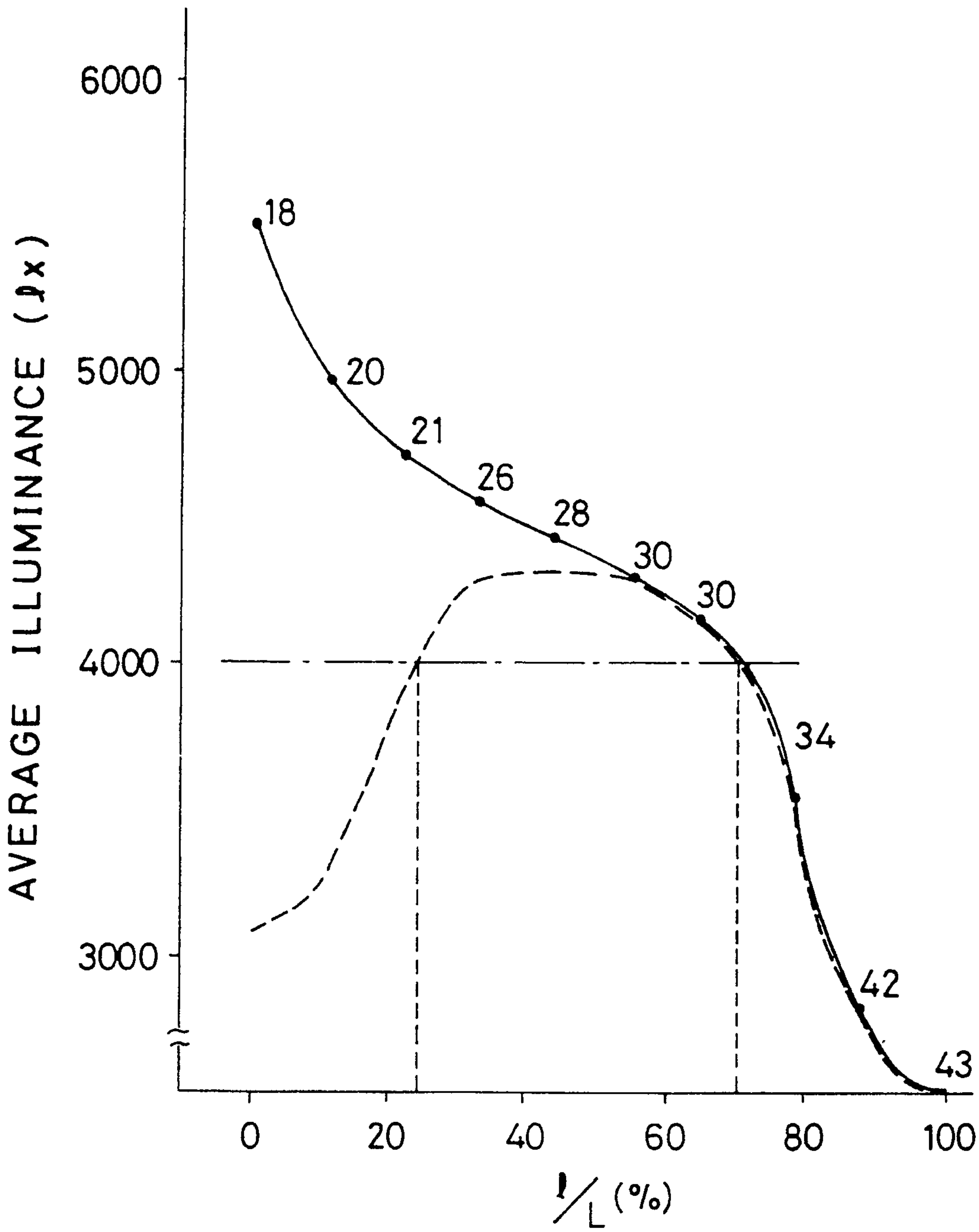

6000
5000
4000
3000
AVERAGE ILLUMINANCE (lx)
18
20
21
26
28
30
30
34
42
43
0
20
40
60
80
100
l/L (%)

FIG.11

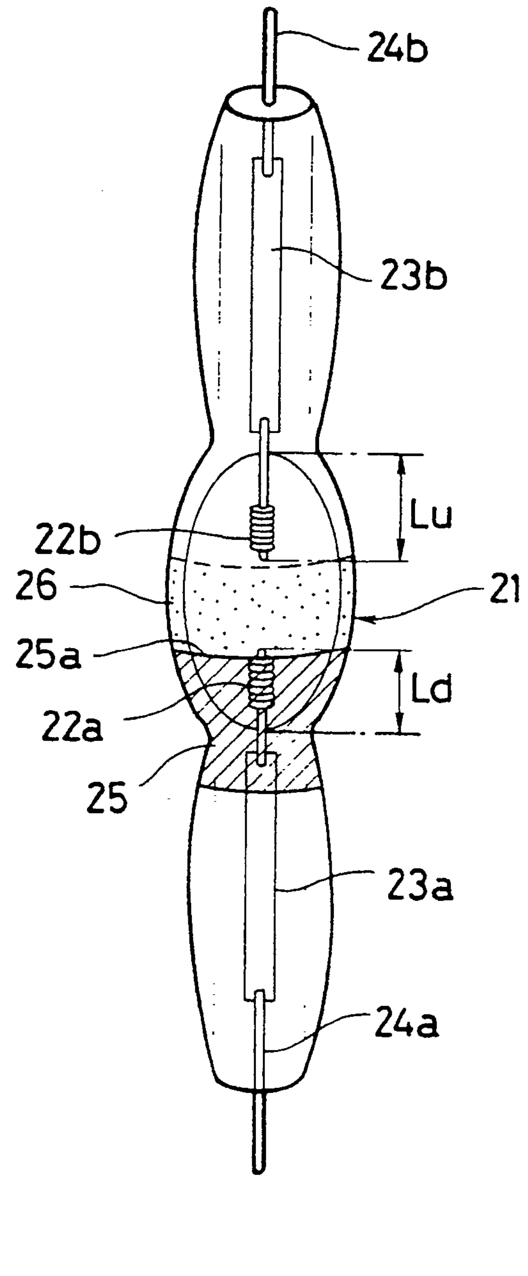


FIG.12